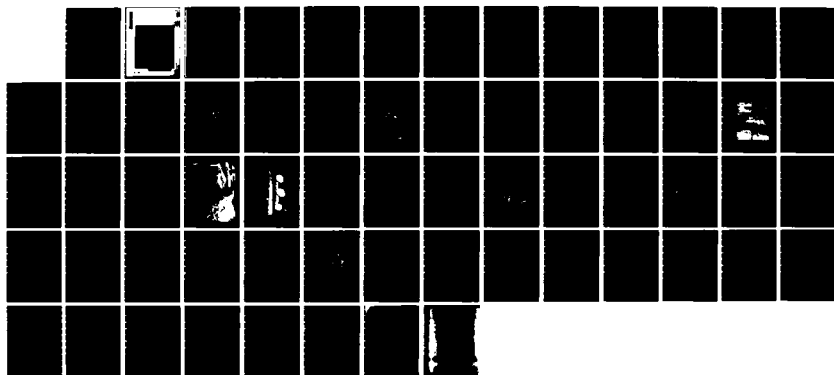


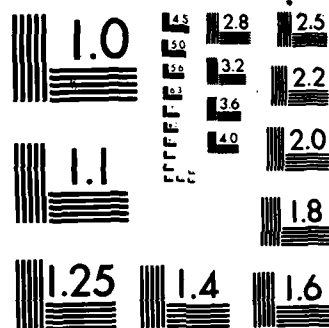
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FINAL REPORT

Contract DAAH01-83-P-0805

VEHICLE CONCEPT FOR A ROBOTIC MISSILE LAUNCHER

By

Dr. Charles R. Evces, Associate Professor
Department of Mechanical Engineering
The University of Alabama

and

Mr. Paul D. Fearing
Graduate Research Assistant

Prepared for

U. S. Army Missile Command
Redstone Arsenal, Alabama 35898

May 1983

BER Report No. 300-100

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TECHNICAL REPORT NO. TR-RL-CR-84-2

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I. INTRODUCTION

In light of the Airland Battle 2000 concept of the new Army, the Army Missile Command is interested in the concept of a mobile robotic missile launcher weapons system. The system is to consist of several vehicular components. Existing missile launchers are to be mounted on highly mobile, unmanned vehicles to be remotely controlled from a manned control center. The control center along with a supply center will also be mobile and will operate from positions close to but not directly in the battlefield environment.

The missile launcher vehicle is the subject of this study. The vehicle is to be remotely controlled and capable of mobility over a wide variety of terrains. The vehicle is also to be compatible with a variety of existing missile launching systems. New battlefield mobility concepts are to be considered in the conceptual design of the vehicle.

II. SCOPE OF WORK

The scope of work in this study includes the following tasks:

1. Conduct a literature search on the subject of roving and remotely controlled vehicles to determine:
 - A. What roving vehicles are available from major manufacturers that are currently remotely controlled?
 - B. What roving vehicles are available from major manufacturers that are not now, but could be converted to be remotely controlled?
 - C. What is the state-of-the-art of methods of mobility that can be utilized in the conceptual design of new special purpose vehicles?
 - D. What are the major problem areas associated with the remote control of vehicles (i.e. communications, controls, vision, etc.)?
2. Evaluate current designs and new concepts of vehicles for application to a robotic missile launcher.
3. Provide at least two final design concepts of a vehicle to be developed based on:
 - A. A currently available commercial vehicle.
 - B. A proposed special purpose vehicle.

III. DESIGN CONSTRAINTS

The design constraints for a preliminary conceptual study are necessarily sketchy. The mission profile for the unmanned missile launcher is the primary constraining factor. Mobility over a wide variety of terrains, control from a remote location, and ability to transport the required payload are definite requirements of this mission profile. The battlefield environment in which the vehicle is expected to operate is another constraint on the vehicle design.

The mobility requirement obviously stems from the fact that the battlefield terrain is an unknown variable. The vehicle must be able to operate on as wide a variety of the possible terrains as is practical. The control constraint requires that the vehicle be adaptable to the chosen mode of remote control if not already equipped with it. The maximum projected weight and length of the payload is about 675 lbs and 61 inches, both for two pods of 2.75 rockets and launching equipment. This is the heaviest and longest anticipated combination of missiles, launcher, tracking device, and other equipment. The work in this study is done under the assumption that the vehicles will be operating at the front line of battle. In this situation, the vehicles would presumably not encounter men, but the front line of tanks.

IV. LITERATURE SEARCH

An extensive computer-aided literature search was conducted in order to investigate the state-of-the-art of mobility concepts and problems associated with the remote controlling of vehicles. Through the Dialog Information Services, the following information data bases were searched:

NTIS--National Technical Information Service
COMPENDEX--Engineering Index Inc.
INSPEC--Institution of Electrical Engineers
TRIS--U. S. Dept. of Trans. and Trans. Res. Board
ISMEC--Cambridge Scientific Abstracts
GPO--Government Publications Office
Comprehensive Dissertation Abstracts--Xerox Corp.

Through the Redstone Information Services the following information data bases were searched:

DTIC--Defense Technical Information Service
Document Ref. NASA Searches.

Key words are an important factor in computerized literature searching. After working with various information indexes and thesauruses the following list of key words and reference headings was compiled for each.

ENERGY DATA BASE

air cushion vehicles
electric powered vehicles
flywheel powered vehicles
hybrid electric powered
land transport
space vehicles
trackless vehicles

ENGINEERING INDEX

air cushion
ground effect
magnetic suspension
off road operation

INSPEC THESAURUS

electric vehicles
locomotives
remote control
road vehicles
space vehicles
telecontrol
telecontrol equipment

NASA THESAURUS

amphibious vehicles
electric hybrid vehicles
electric motor vehicles
ground effect machines
lunar roving vehicles
lunar surface vehicles
Lunokhod
magnetic levitation
manned surface vehicles
motor vehicles
proving research vehicles
remote control
remotely piloted vehicles
roadway powered vehicles
robots
rocket propelled sleds
roving vehicles
sleds
surface effect ships
surface vehicles
tracked vehicles
tractors
walking machines

Some words such as mobility and military vehicles were not found as references in the indexes, but were still used as search key words. The computerized literature searches generated lists of articles and abstracts likely to contain pertinent information to this contract. The most promising articles were then compiled into a bibliography list and ordered through various channels. These articles are tabulated in the list of references.

IV.1 Mobility Concepts

The literature search uncovered numerous articles concerning new mobility concepts. The concepts ranged from mobility aids for conventional wheeled vehicles to rather far-fetched new methods of mobility. A discussion of those concepts worthy of mention follows.

There are various methods of improving the mobility characteristics of wheeled vehicles. Among the most obvious are incorporating 4 wheel drive and using large tread tires. Another method of improving mobility is by lowering the ground contact pressure. This can most easily be done by using lower pressure tires. This gives the vehicle a larger "footprint" and effectively lowers the contact pressure. A more advanced system based on the same idea is a centrally variable tire pressure system. With this type system, the tire pressures can be varied from inside the vehicle according to the type of surface encountered. In this way, high tire pressures can be used for road travel to maximize mileage, and progressively lower pressures can be used as the terrain becomes harder to traverse. Another interesting concept involving the tires is the run-flat tire.^{1,2} These are tires that through their structural strength, can still function while deflated. This could prove valuable in battlefield conditions where tires could be easily punctured. One final method of increasing mobility for

wheeled vehicles is by making them pseudo-tracked vehicles. There is a product called "UNA-Track" (see Fig. 1) which replaces the wheels on a four wheel drive vehicle with independent track assemblies on a one-for-one basis.³ Army testing of these devices showed that they significantly improved mobility characteristics, but caused problems requiring modifications to the vehicles. Durability of the UNA-Track kits was also questionable.

Tracked vehicles in general have very good mobility because of their large footprint and low ground pressure. They tend to make the vehicle heavy and expensive, however. An interesting alternative is the "Elastic Loop Wheel" (see Fig. 2) developed by the Marshall Space Flight Center (MSFC) in work with a mobile Viking Lander.⁴ Elastic loops consist of one-piece self-supporting bands of high strength material and provide a high ground contact area without the weight of a full tracked vehicle. The loop differs from conventional caterpillar tracks in that there are no bogies or other devices to carry the load of the vehicle. The loop itself supports the load from the contact surface to load rollers mounted at the top of the assembly. The loop acts as a spring as well as the wheel and is the only unsprung mass in the system. In testing by the Army this concept has reportedly been plagued by problems of the loop breaking or dislodging.

Articulated vehicles, both wheeled and tracked, provide increased mobility over rough, irregular terrain. Obstacle

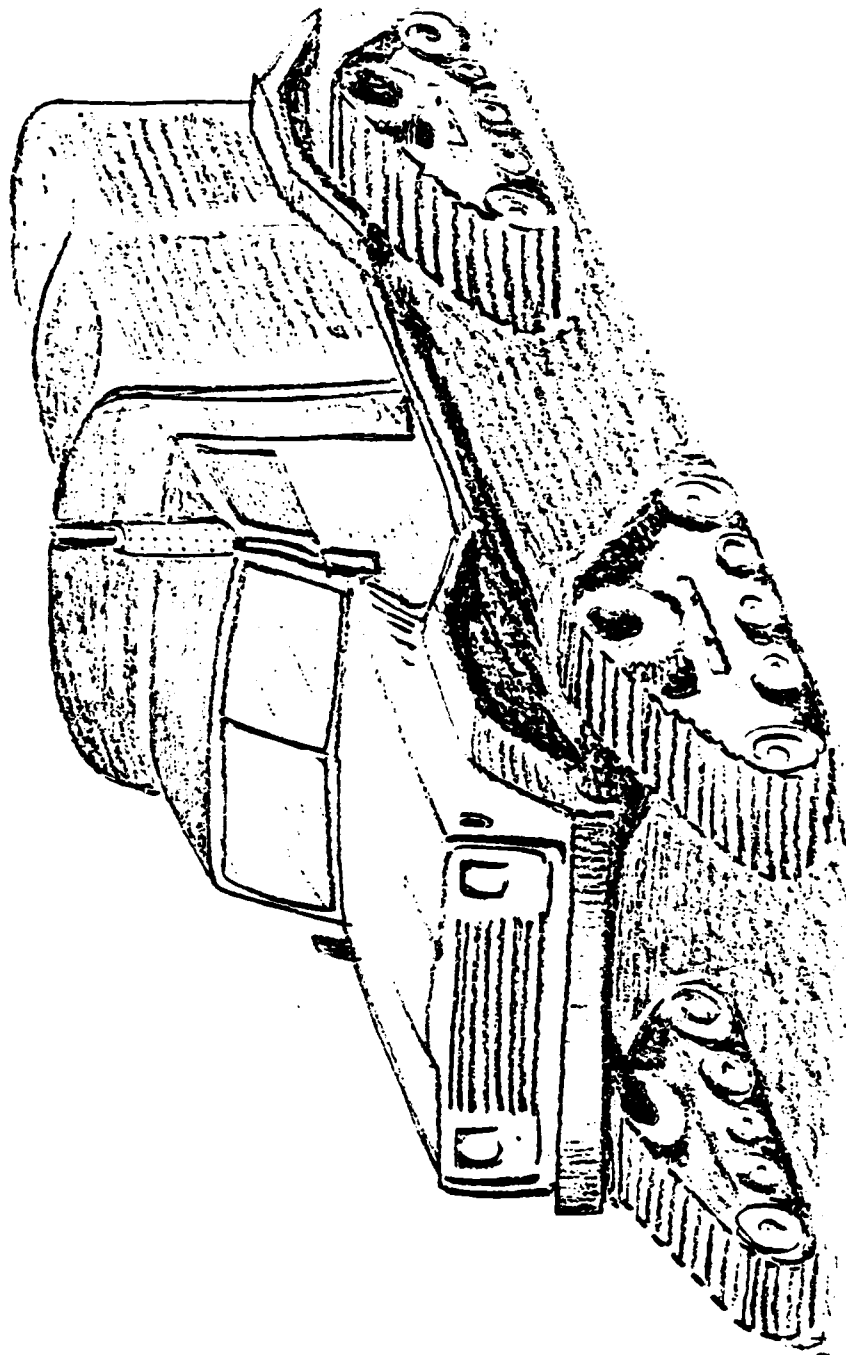


Fig. 1 UNA-Track Kit

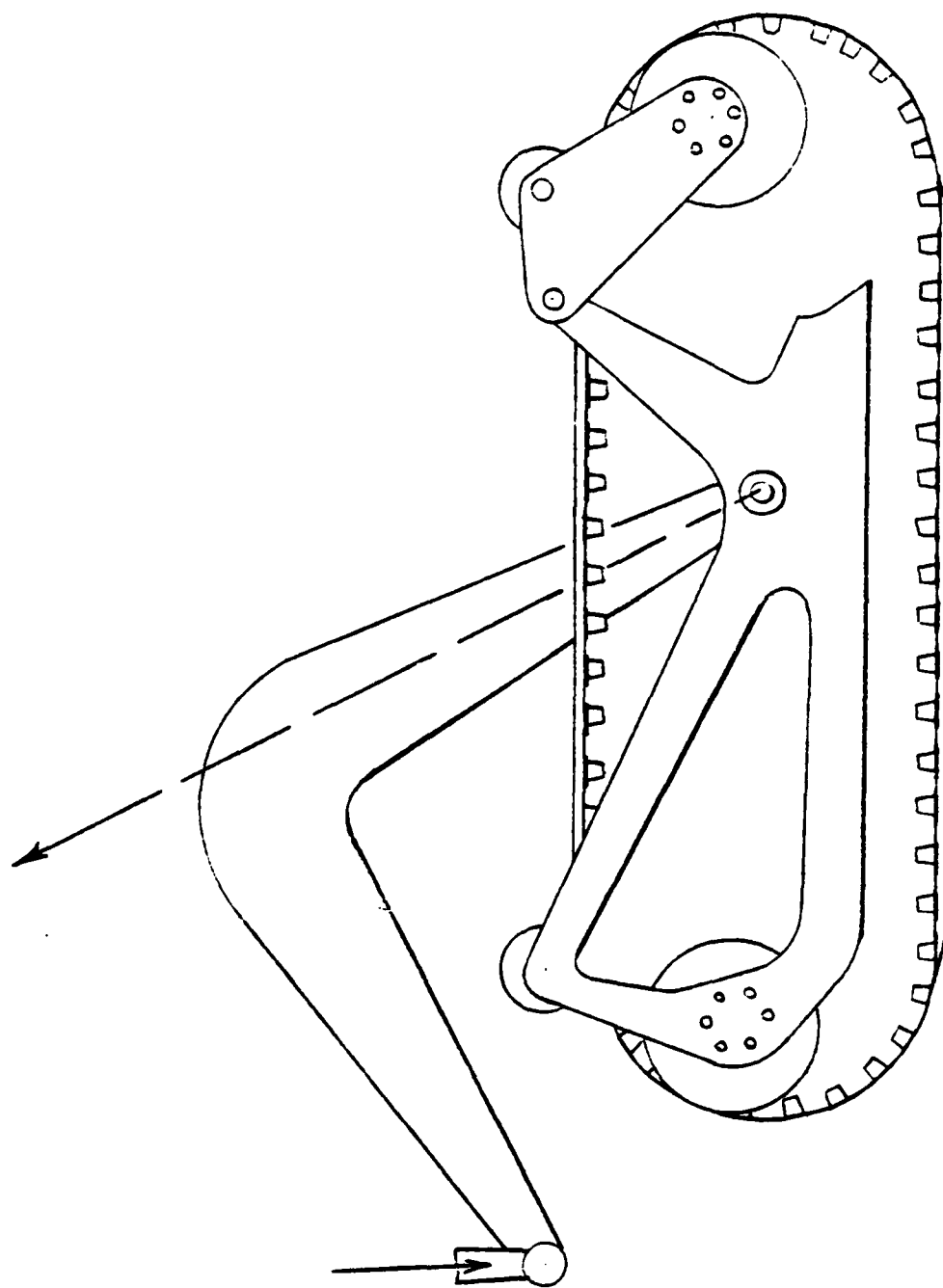


Fig. 2 Elastic Loop Wheel

negotiation can be greatly improved using two or three unit vehicles connected with articulated joints. This allows the vehicle to remain in contact with the ground for a very high percentage of the time. An example of this type vehicle is the Army's M571 articulated track vehicle⁵ (see Fig. 3). Both units of the M571 are powered by an engine in the front unit. Power is transmitted to the rear unit through a joint that permits angular movement in three planes of motion.

Another way in which articulation can aid mobility is with controlled articulated suspension.⁵ This concept combines the good highway performance of a wheeled vehicle with the ability to maneuver in extremely difficult soft off-road conditions. This is accomplished with the controlled articulated suspension and individually powered wheels (see Fig. 4). Each of the wheels is mounted on a hinged member much like a leg which is mounted to the hull through a joint that allows limited and controlled rotation. The position of the wheels can be controlled fore and aft, as well as vertically, through actuating cylinders. The vehicle operates identical to a conventional wheeled vehicle whenever able, but when extremely soft soil is encountered, the vehicle can go into the walking mode. The legs then lift up and advance one at a time. The frame then moves back up over the legs and the process is repeated to accomplish forward motion.

The biggest problem with articulation is that it complicates the vehicle mechanically and with respect to

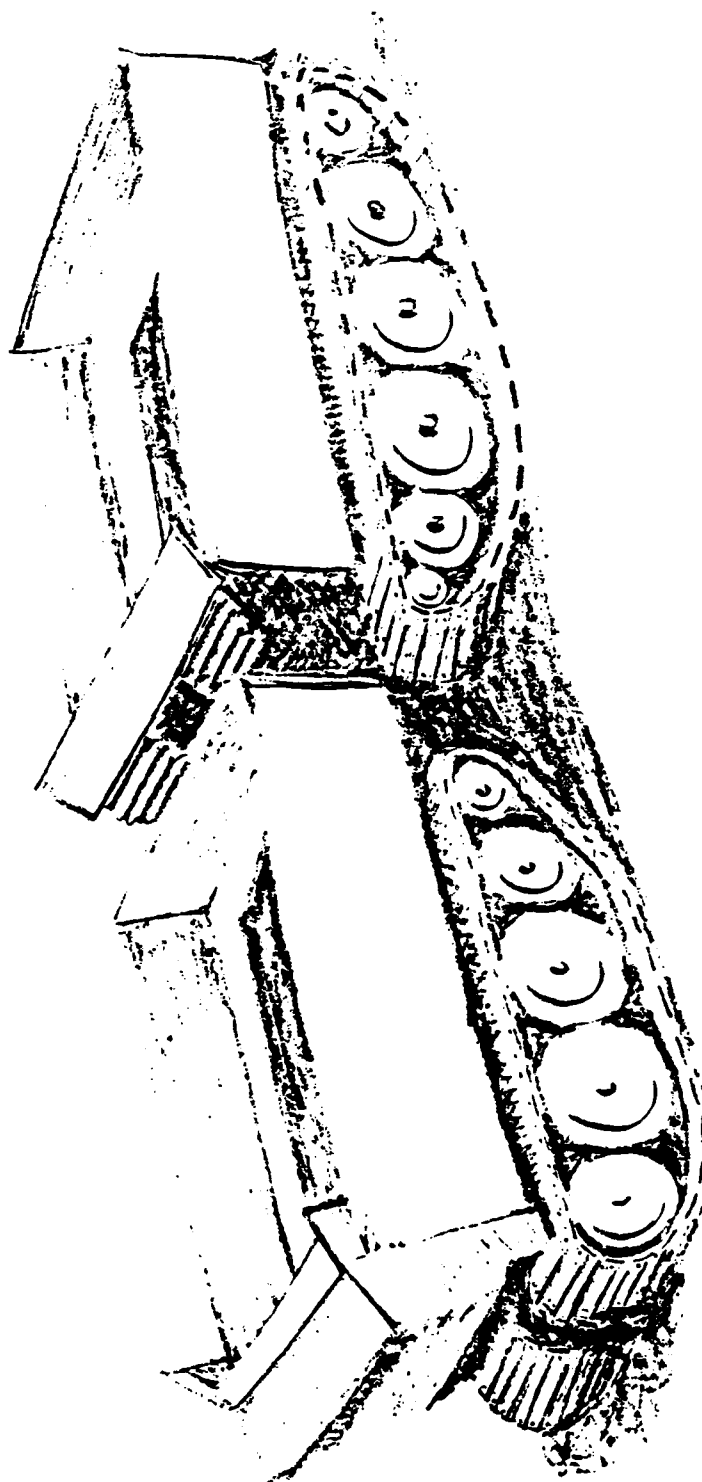


Fig. 3 M571 Articulated Track Vehicle

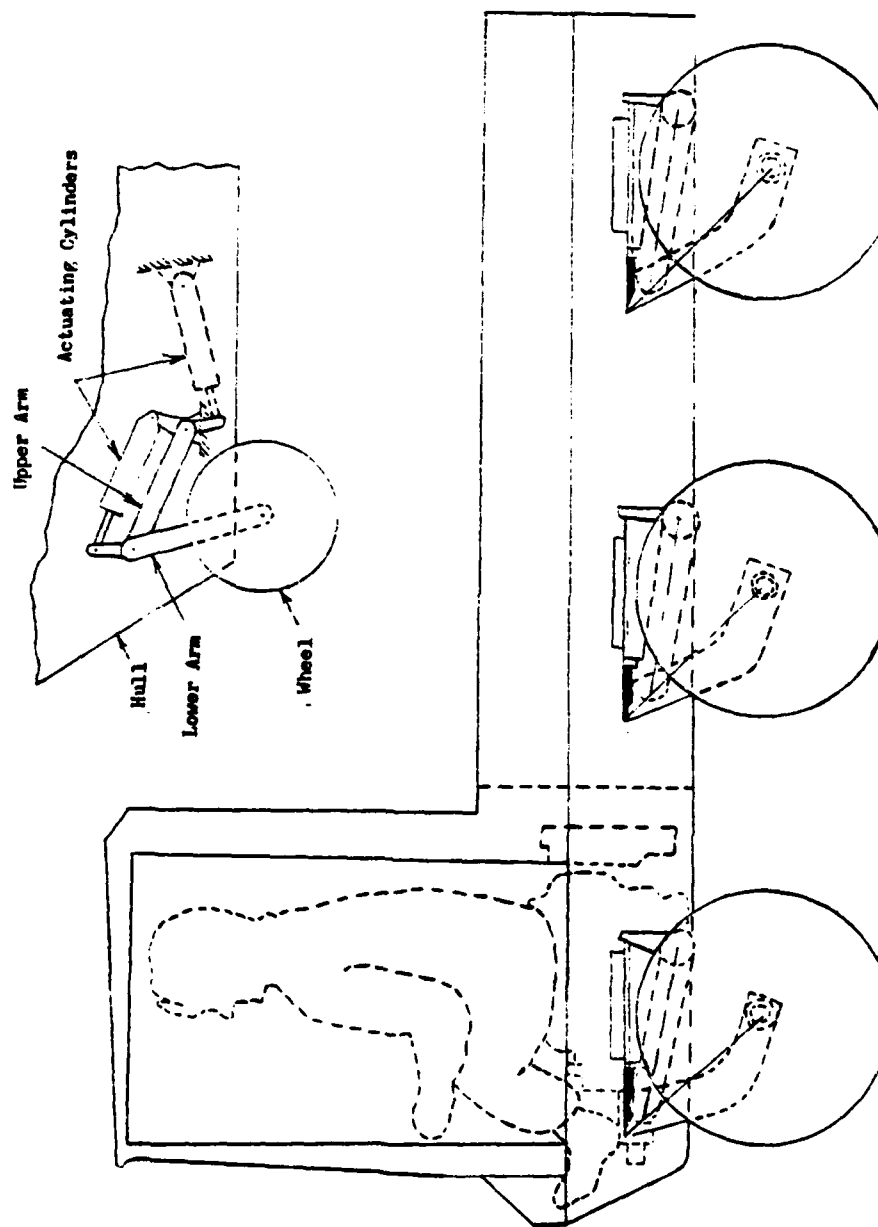


Fig. 4 Articulated Suspension Vehicle

control. The increased mobility that may be valuable a very small percentage of the time is not necessarily worth the price paid in simplicity.

The air cushion vehicle or surface effect ship is an alternate method of mobility to be considered. The biggest problem with air cushion vehicles is in controllability and maneuverability.^{6,7} Over irregular terrain, problems with yaw and sideways stability arise. The air cushion surface contacting hybrid vehicle is a step toward solving this problem. This type vehicle has the advantage of low ground pressure along with improved handling characteristics due to wheels or tracks contacting the ground. The wheels or tracks are used not only as propulsive devices, but also as a yaw and sideways control device for the air cushion. An auxiliary air propulsion system may be necessary for off-road application.

IV.2 CONTROL CONCEPTS

The control of an unmanned vehicle is a very interesting problem. The control requirements of the vehicle for this study are fairly demanding. A vision system will have to be used to navigate and locate potential targets. This system will have to communicate with the controller in the central control location. Some sort of artificial intelligence will probably also be required, so that the controller doesn't actually have to "drive" the vehicle all the time. At least enough intelligence to enable the controller to give a command ordering the vehicle to go from point A to point B would be desirable. This would enable the operator to deal with more than one vehicle at a time.

A very accurate and reliable control link is required in order to accomodate these requirements. The terrain and atmospheric conditions on the battlefield are unknown and highly variable. These considerations, along with enemy jamming, eliminate radio type control links from consideration immediately. This leaves fiber optics and autonomous control to be considered.

A tremendous amount of research has been done in the field of autonomous control of roving vehicles for application to Lunar and Mars rovers. Autonomous control is an absolute necessity for Mars rovers because of the large

communication time from Earth. One outgrowth of this is a bread-board autonomous vehicle developed by NASA's Jet Propulsion Laboratory in Pasadena, California.^{8,9} Their vehicle can, with its onboard navigation system and rangefinding and touch sensors, be put in an unknown environment and find its way around obstacles taking the most efficient path to a desired goal. Autonomous control in the full sense of the word is by no means, however, off-the-shelf technology. Extensive research would be required in order to develop such a system for this application if at all possible.

Much more within the reach of today's technology is a system controlled by a fiber optic link. This system would consist of a "spool" of disposable fiber optic cable that pays out with very little tension behind the vehicle. This link provides accurate, secure control as long as the fiber is intact. For the battlefield environment assumed in this study, the biggest threat to the cable would probably be getting run over by various vehicles. The casing enclosing the fiber optic cable will have to be sufficient to protect it from this problem. Because of its large carrying capability and reliability, fiber optics appears to be a very promising alternative for the control of this vehicle.

V.1 EXISTING ROVING VEHICLES--REMOTE CONTROLLED

There are very few remotely controlled roving vehicles currently in use or production. The military is interested in remote controlling roving vehicles for a variety of reasons. Virtually all of the work done in this area is from military research and development contracts.

The Army's Surrogate Fast Attack Vehicle (SFAV) Program has provided one interesting vehicle (see fig.5,6). The SFAV is basically a beefed-up dune buggy very similar to those that compete in off-road races such as the Baja 1000. The SFAV was built by Chenoweth Racing Products Inc. who was subcontracted to Emerson Electric Co. The SFAV is to be utilized in a variety of modes from unmanned reconnaissance to anti-armor by mounting a variety of weaponry from a 30 mm chain gun to TOW missiles on the vehicle. The vehicle weighs about 1500 lbs. and is capable of road speeds over 80 mph. The Army has designed a remote control system for the SFAV but it is currently not being used in the remote control mode. The SFAV is currently being concept tested by the 9th Infantry Division at Ft. Lewis, Washington.

A similar vehicle called the Sandaire Land Vehicle (SLV) was built for the Navy by San Diego Aircraft Engineering Inc. (see fig. 7,8). The vehicle is officially designated by the Navy as QLT-1C (Mobile Land Target). It is used as a remote controlled target to sharpen the bombing

FAST ATTACK VEHICLE

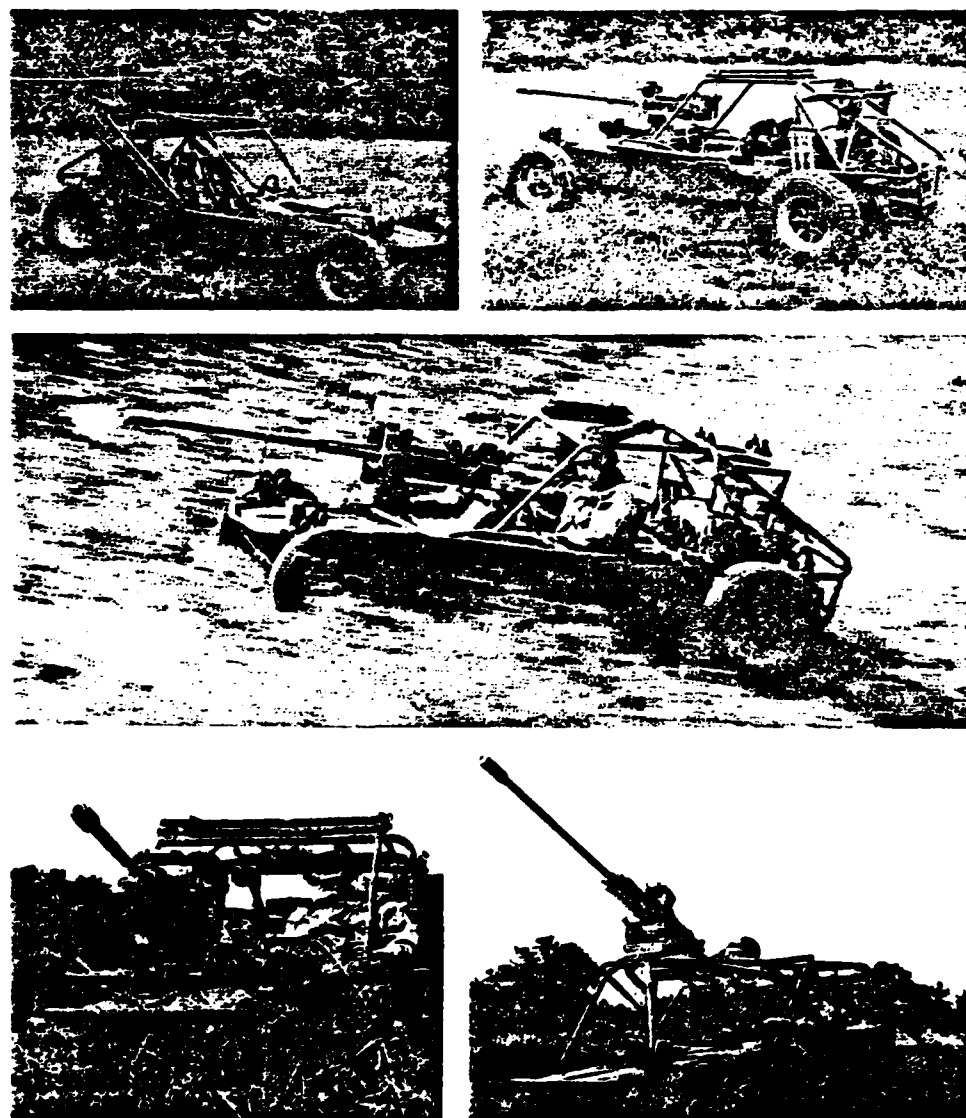


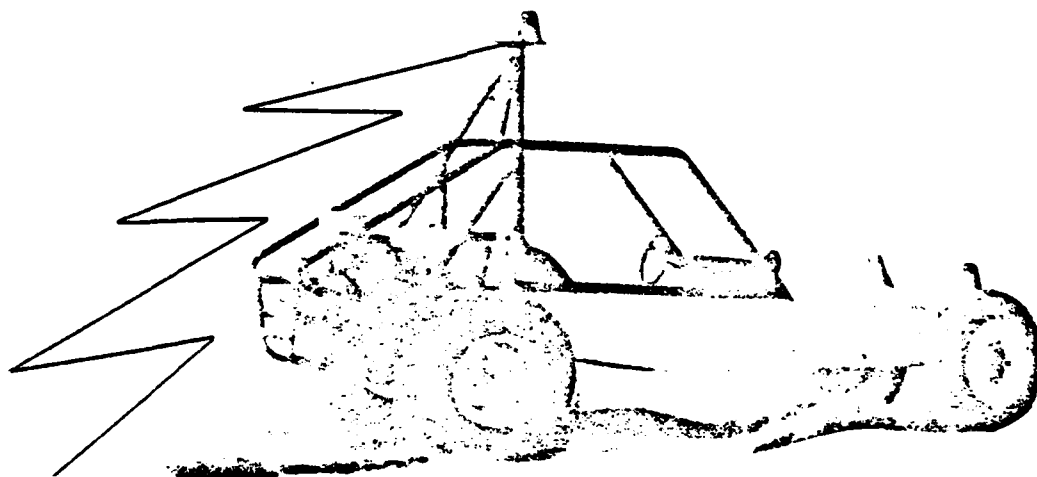
Fig. 5

Emerson Electric Fast Attack Vehicle

Weight:	(gasoline engine) 1540 lbs.
Maximum Payload:	presently over 900 lbs. Army spec. 1300 lbs.
Length:	150 inches
Height:	60 inches
Ground Clearance:	over 12 inches
Wheelbase:	100 inch class
Power Train:	
	(Standard) gas, air cooled, 94 HP at 4400 rpm
	(Optional) diesel, water cooled, 90 HP at 4200 rpm
	(Optional) diesel h.p., water cooled, 100 HP at 4200 rpm
Transaxle:	4-speed, close ratio synchromesh, 5.4:1 axle ratio
Maximum Road Speed:	85 mph
Acceleration:	0-60 mph under 12 sec. with 480 lb. load
Chassis:	high strength tubular frame with unitized roll cage
Brakes:	front and rear drum
Steering:	rack and pinion
Shock Absorbers:	high performance; 2 per each front wheel 3 per each rear wheel

Fig. 6

RADIO CONTROLLED S.L.V.



SANDAIRE LAND VEHICLE



**REMOTE CONTROL CONSOLE
AND COMMAND TRANSMITTER**

APPLICATIONS

Remotely Controlled Target
 Unmanned Reconnaissance with TV and Sensors
 Unmanned Radiation Detector
 Unmanned Target Tow Vehicle
 Remotely Controlled Decoy
 Unmanned or Manned Weapons Delivery
 Manually driven off-road personnel carrier



SANDAIRE

San Diego Aircraft Engineering, Inc.

3777 Gaines Street, San Diego, California 92110 - (714) 291-2512

Fig. 7

SANDAIRE LAND VEHICLE

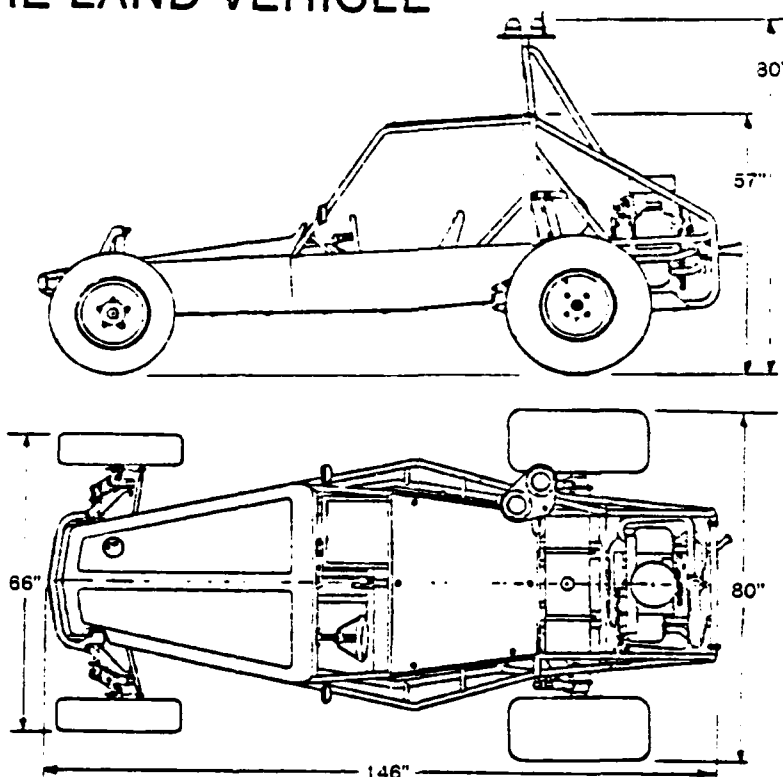
FRAME:
Tubular Welded
Steel

POWER PLANT:
65 HP Air-Cooled
Gas

DRIVE TRAIN:
Auto Trans &
Transaxle

SPEED:
55 MPH

WEIGHT:
1500 lbs



The SLV can be driven and operated remotely or it can be operated and driven manually.

Remote Controls consist of:

Engine Start/Stop	Shift - FWD-NEUT-REV
Brake/Throttle	Steering
Red Beacon	Headlights
Emergency Stop	Power On/Off

Command Control System consists of:

DRW/29 Receiver/Decoder or equivalent
SANDAIRE Transmitter/Encoder P/N 124SA4001
Frequencies 400 through 450 MHz



SANDAIRE

San Diego Aircraft Engineering, Inc.

3777 Gaines Street, San Diego, California 92110 - (714) 231-2512

Fig. 8

skills of Navy pilots. Remote control is line-of-sight and is, therefore, limited to about two miles. Control is typically accomplished by a controller and an observer with field glasses in a viewing tower. The SLV is virtually the same size and configuration as the SFAV, but the top road speed is only about 55 mph.

Grumman Aerospace is working with the Ballistic Research Lab on a robotic mobile mine vehicle called Ranger (see fig. 9).¹⁰ The vehicle weighs under 100 lbs., is remote controlled through a disposable fiber optic link, and can achieve relatively high speeds under off-road conditions due to a high sprung-to-unsprung mass ratio. Large suspension travel and pitch articulated "diamond" wheel configuration allow vertical obstacle negotiation of sixty percent of wheel diameter. A prototype of the Ranger is to be built for BRL by late summer 1983. This vehicle is mentioned here, despite its size disparity with the requirements of this study, because of its remote control link and promising mobility design features.

Grumman is involved with another remote control vehicle of interest. The Remote Controlled Tactical Vehicle (RCTV) was originally a full scale model for lunar exploration and has recently been refurbished with respect to on board controls and leased to the Army (see fig. 10,11). The RCTV is a highly maneuverable, stable, low to



Fig. 9 Ranger

REMOTE CONTROLLED TACTICAL VEHICLE

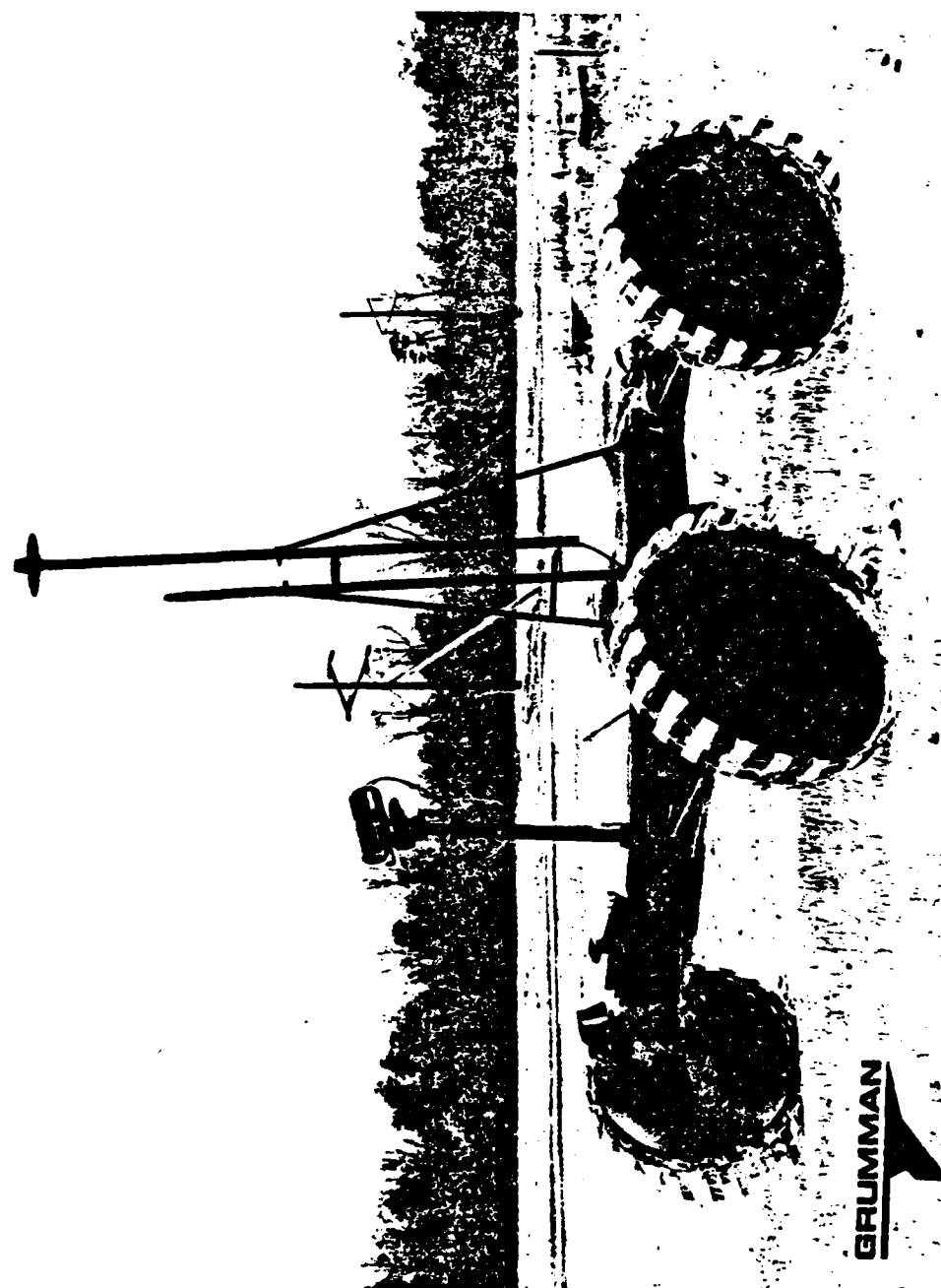


Fig. 10

Grumman Aerospace Remote Controlled Tactical Vehicle

Weight:	1100 lbs.
Wheel Base:	87 inches
Wheel Tread:	120 inches to cleat centerline
Ground Clearance:	19-20 inches under chassis and suspension arms
Wheels:	40 inch diameter, low ground pressure, cleated fiberglass cone (Grumman patent)
Power Supply:	8, 12V lead acid batteries
Wheel Drive:	1.2 HP D.C. series motor and 60/1 gearbox at each wheel
Steering:	Reversible D. C. actuator driving articulated joint between the chassis modules; electric "differential" inherent in drive circuit
Speed Range:	0-20 mph
Turn Radius:	23 feet to vehicle centerline
Maximum Slope:	(climbing) 25 degrees in soft sand
Maximum Obstacle Negotiation:	16 to 18 inch step obstacle; 25 to 30 inch trench
Pull/Weight Ratio:	0.6
Controller:	Fully transistorized pulse width modulator; short circuit protected, adjustable peak current limit, thermal overload protection

Fig. 11

moderate speed off-road vehicle built to demonstrate Grumman's mobility and remote control concepts. Candidate payloads and controlling systems could easily and inexpensively be mounted on the vehicle in order to test and evaluate. This bread-board vehicle concept appears attractive especially since the Army presently has access to the vehicle.

The Army Tank Automotive Command (TACOM) is working on a vehicle called the Remote Control Countermine Vehicle. The vehicle is based on an M47 tank remotely controlled by radio. The tank fires an exploding line out onto a mine field, then follows the cleared path the line has created. As it does so, it marks the safe lane with flags. TACOM is also investigating the possibility of using autonomous capabilities to make the vehicle follow the exploding line without operator control.

Another remote control vehicle is in use at Ft. Knox. Old 114 Reconnaissance Vehicles are being used as remote controlled target vehicles. They are being used for hit probability tests for pilots. The remote control system used is the same as for the Countermine Vehicle.

V.2 EXISTING ROVING VEHICLES--NOT REMOTE CONTROLLED

There are a variety of vehicles that are not currently remotely controlled that might be adapted to remote control for use as an unmanned mobile missile launcher. Of those, the following were found to be the most promising. Again, the military has prompted much research and development work in the field of off-road and multipurpose vehicles. From the High Mobility Multipurpose Wheeled Vehicle (HMMWV) program comes two promising alternatives.

In July 1981, the Army Tank Automotive Command (TACOM) awarded AM General, Chrysler Corporation, and Teledyne Continental each a contract to build 11 prototype vehicles for further testing and evaluation. The AM General "Hummer" is a product of that contract (see Fig. 12,13). The layout of the vehicle is conventional with the engine in the front, driver and passenger in the center, and passengers/cargo in the rear. The design is such that the vehicle can be configured for a variety of uses with little notice. Standard automotive components are used extensively in order to reduce initial procurement and total life cycle costs. The Hummer weighs about 5000 lbs. and has a maximum payload of about 2500 lbs. A maximum road speed of 70 mph and a range of over 300 miles are complemented by mobility characteristics such as 20 inch vertical obstacle negotiation and run-flat tires. If required, a central tire-pressure system is available.

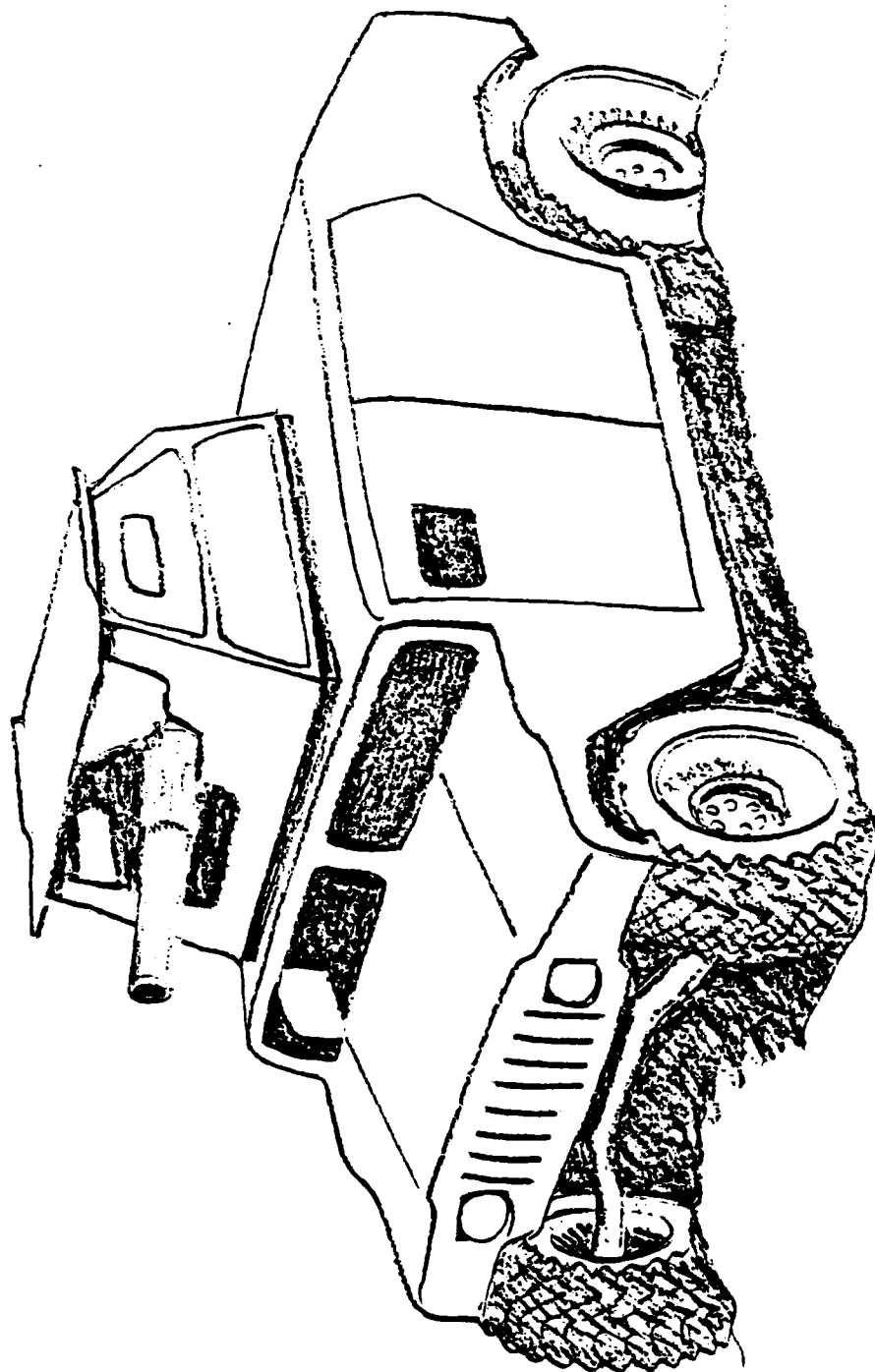


Fig. 12 Hummer

AM General Hummer

Weight:	4960 lbs.
Maximum Payload:	2500 lbs.
Length:	186 inches
Height:	69 inches
Ground Clearance:	16 inches
Wheelbase:	130 inches
Engine/Trans.:	Chevrolet 6.2l V-8 diesel--130 HP with Chevrolet 700R4 auto. trans.
Maximum Road Speed:	70 mph
Acceleration:	0-30 mph in under 8 seconds 0-50 mph in under 22 seconds
Range:	325 miles
Suspension:	double A-frame, independent with hydraulic double acting shocks at each wheel
Steering:	Saginaw 708, integral power
Brakes:	(main) hydraulic, disc front and rear (rear) mechanical, all disc
Angle of:	approach--70 degrees departure--45 degrees
Maximum Gradient:	60%

Fig. 13

The (4x4) Expanded Mobility Truck designed by Chrysler has since been taken over by General Dynamics (see Fig. 14,15). The configuration of the vehicle is again conventional with engine in front, driver and passenger in center, and cargo in rear. Standard commercial components have been used wherever possible in the design. The vehicle weight, maximum payload, and maximum range are about the same as the AM General Hummer. The maximum road speed, however, is significantly greater at about 90 mph with the Chrysler engine. Outstanding mobility has been accomplished with a new tread design, high ground clearance, high wheel travel and soft springs at all wheel stations. Unusually rugged terrain can be negotiated with a 90 degree approach angle, a 140 degree breakover angle, and a 61 degree departure angle.

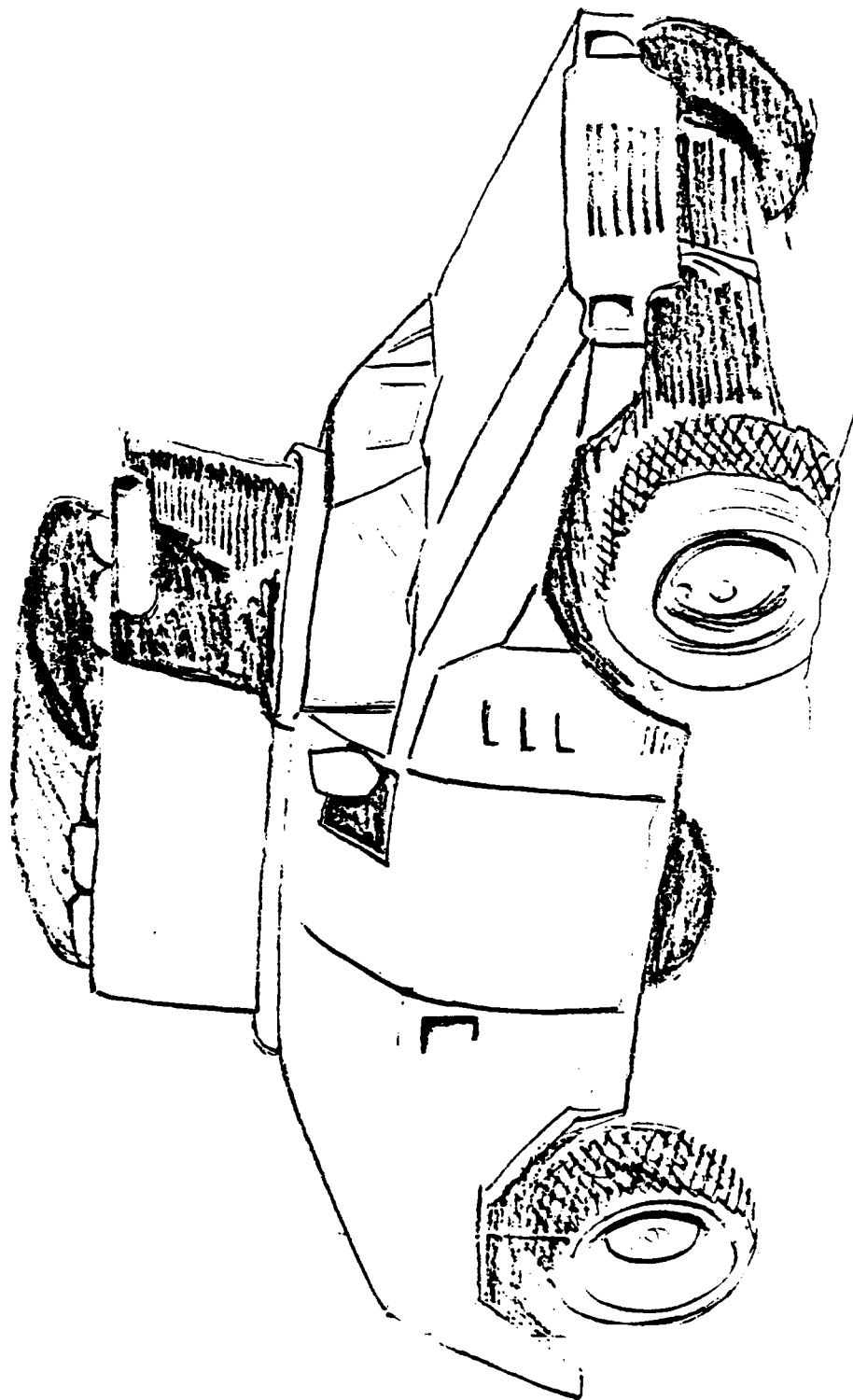


Fig. 14 General Dynamics HMMWV

General Dynamics HMMWV

Weight:	5071 lbs.
Maximum Payload:	2500 lbs.
Length:	177 inches
Height:	(overall) 77 inches
	(reduced) 60 inches
Ground Clearance:	13 inches
Wheelbase:	124 inches
Engine:	Chrysler 360-1 petrol--195 HP or Deutz F8L-610 V-8 diesel--160 HP
Gearbox:	Chrysler A727 auto.
Maximum Road Speed:	(Chrysler) 90 mph (Deutz) 75 mph
Range:	(Chrysler) 310 miles (Deutz) 500 miles
Suspension:	(front) double-A frame, independent, with hydraulic shock at each wheel
	(rear) trailing arm, solid axle, with hydraulic shock at each wheel
Brakes:	(main) hydraulic, disc front, drum rear
	(parking) mechanical, rear drums
Angle of:	approach--90 degrees departure--60 degrees

Fig. 15

VI. DESIGN CONCEPTS

Numerous concepts were considered as possible design alternatives. Lists of locomotion, power supply, and transmission methods generated follow below.

LOCOMOTION

wheels
tracks
air cushions
walking devices
vibrating/hopping devices
sleds/runners
worms/screws

POWER SUPPLY

internal combustion engine
electric motor and battery
turbine engine
jet engine
steam engine
bottled gas
springs/energy storage

TRANSMISSION

gears
hydraulic
traction drive
continuously variable
belts
chains
linkages

These concepts must be evaluated based on the following design criteria.

cost	acceleration
durability	transportability
reliability	controllability
mobility	remote control adaptability
maneuverability	existing commercial hardware
speed	

Many of the alternatives can be easily eliminated from consideration, because they are not logical methods for

accomplishing this task. The locomotion methods can be narrowed down to wheels and tracks simply because these two choices are the only ones that have a sufficient amount of existing hardware and design research to expect good reliability. A tracked vehicle has inherently better mobility than a wheeled vehicle because of its lower ground contact pressure. However, a tracked vehicle is much more expensive, slower, less maneuverable, and less transportable than a wheeled vehicle. For the tracked vehicle to be worth its extra cost, it must survive longer than the wheeled vehicle, which requires that it be armored. This means more money and weight. For these reasons, the wheeled vehicle appears to be more attractive as long as it has the required mobility.

Internal combustion engines and electric motors are the only two power supply alternatives that are cheap, efficient, and easily controllable. Internal combustion engines, however, have greater acceleration capabilities, do not have the problem of battery drain, and have more existing commercial hardware. Another criteria to consider is the thermal signature. Since virtually all existing Army ground vehicles are powered by internal combustion engines, an electric motor might give the vehicle a unique thermal signature that would make it easily recognizable to the enemy. The internal combustion engine, then, appears to be the best choice for power supply. For easy starting and quick acceleration, a gasoline burning engine is better than

a deisel. The simplest and most durable method of cooling the engine is an air cooling scheme.

The choice of locomotion and power supply directly affect the choice of transmission. The conventional transmission used with an internal combustion engine is a system of planetary gears either in a manual or automatic shift mode. A three speed automatic transmission will provide the needed speed range and be more easily adapted for remote control than a manual transmission.

VI.1 DESIGN CONCEPT--EXISTING VEHICLE

Many factors are involved in deciding which vehicle is best for this job. The most important requirements of the vehicle are:

- ability to carry payload
- mobility
- speed
- acceleration
- maneuverability
- ruggedness
- survivability
- transportability
- cost
- remote control adaptability

The Emerson Electric Fast Attack Vehicle, the AM General Hummer, and the General Dynamics HMMWV all have the capability to do this job. The Hummer and the General Dynamics vehicles are very similar in most respects. Since the Hummer was awarded the HMMWV contract¹¹ and will be a part of the Army fleet, it is the most attractive choice of the two. The FAV and the Hummer, then, are the best candidate vehicles.

A comparison of how well the two vehicles satisfy the requirements of this study is necessary to choose the best vehicle. Both have the ability to carry the maximum payload of 675 lbs. (FAV--900 lbs., Hummer--2500 lbs.) The performance and handling characteristics of the FAV would probably be affected more by this maximum payload, simply because it is a larger fraction of the vehicle weight (FAV weight--1540 lbs., Hummer weight--4960 lbs.) The Army

specification for the maximum payload of the FAV is 1300 lbs., so it is likely that further modifications will be made to the suspension in order to reach this figure. If this transpires, the FAV would be even better suited to carry the payload.

The mobility characteristics of the two vehicles are not easily rated. The Hummer has a higher ground clearance (FAV--12 inches, Hummer--16 inches) and the option of a central tire pressure regulation system, but will probably have a higher ground pressure simply because of its much greater weight. Because both vehicles have extensive off road capabilities, a judgement of one over another is difficult in this respect.

The FAV is clearly superior in maximum speed, acceleration, maneuverability, transportability, and cost. Both are equally adaptable for remote control, though no remote control work has actually been done with the Hummer. The Hummer has a slight edge in ruggedness because of its limited armor, its run flat tires, and enclosed engine.

The most important trade-off in this design decision is cost versus survivability. If one vehicle with all its payload costs twice as much as the other, then the vehicle must be twice as survivable. Survivability can be attained through armor or maneuverability or some combination of the two. Difficulties arise when trying to evaluate the survivability of vehicles when such variables as the terrain and enemy fire are unknown. In order to meaningfully

evaluate the survivability of these vehicles, an in depth study concerning their performance in various environments and situations must be conducted. For the purpose of this study, then, the survivability of the two vehicles will be assumed to be similar for lack of a better evaluation.

From this comparison, the FAV appears to be the best choice for the missile launcher vehicle. Several modifications to the configuration would facilitate the most advantageous placement of the missile launcher on the vehicle. Mounting the launcher on top of the roll cage would likely adversely affect handling. Since the vehicle need not be operable in the manned mode, the section of the roll cage over the driver and passenger seats, along with the seats and all other creature comforts, can be eliminated. This leaves an ideal place to mount a platform for the missile launcher and other equipment (see fig. 16). The exhaust from the missile during launching will have to be routed around or over the engine area somehow. This requirement will differ with different missile launching systems. Deflecting plates might be needed to isolate the engine from the missile exhaust. Another modification that might be considered is the addition of run-flat tires. Under battlefield conditions, this could prevent damage to wheels in the instance of tire punctures.

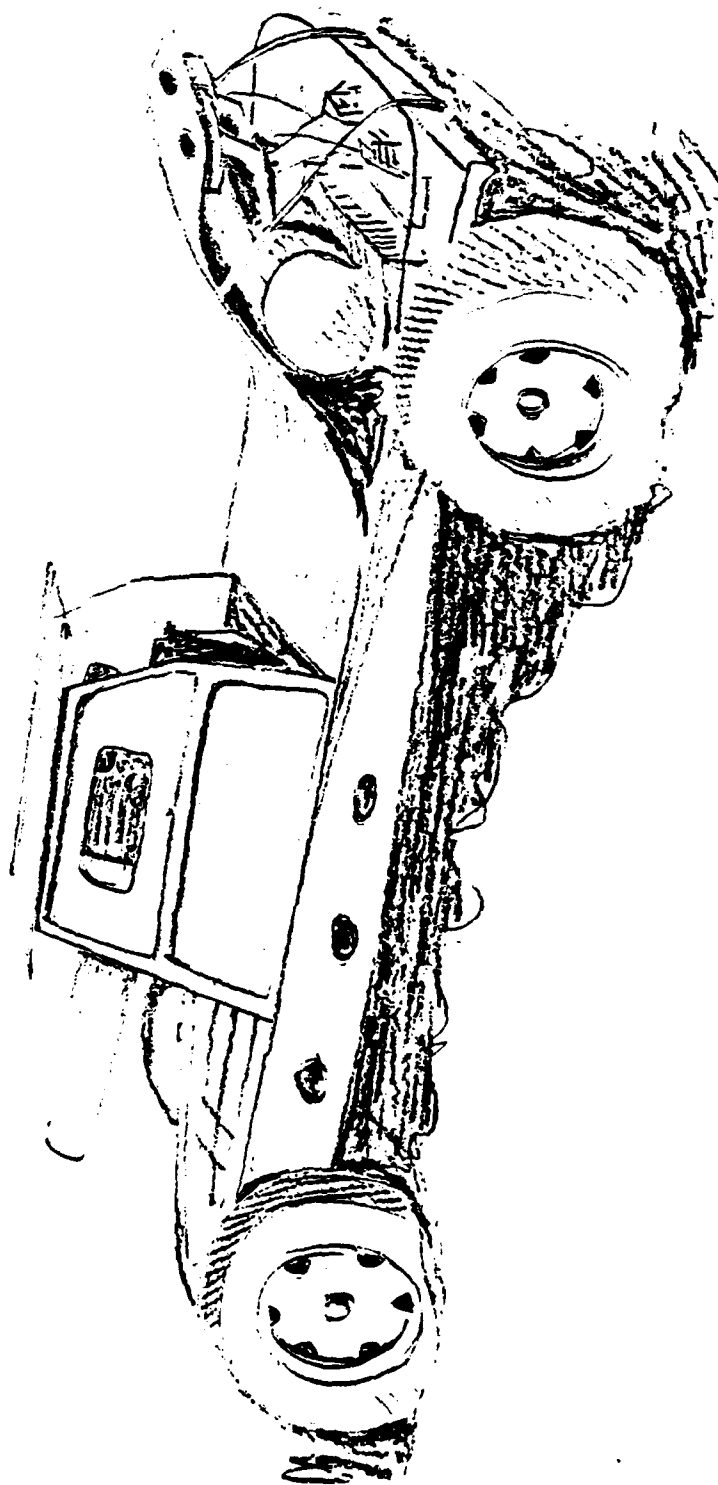


Fig. 16 Modified FAV with TOW Launcher

VI.2 DESIGN CONCEPT--PROPOSED SPECIAL PURPOSE VEHICLE

The design criteria and evaluations discussed in the design concepts section of this report also apply to the design of a proposed special purpose vehicle. This section will simply be a further development of the concepts already stated.

The vehicle will have four run-flat tires as the means of locomotion. The chassis design will consist of a high strength, light weight tubular frame. A flat platform will be mounted on the chassis to accomodate the various payloads. The frame will be mounted just high enough to give sufficient ground clearance for mobility (12-16 inches), but still keep a low profile to the ground. The vehicle will be powered by a 100-150 HP (2-2.5 liter) rear mounted, air cooled gasoline engine. This engine will be driven through a three speed automatic transmission into four wheel drive.

The approximate vehicle weight will be 1500 to 2000 lbs. The platform should be about 100 inches long by 60 inches wide. This will provide ample room to mount the required payloads. The vehicle will have a top speed of at least 70-80 MPH on the road and accelerate from 0 to 60 mph in about 12-15 seconds with a typical payload. A 12 gallon gas tank will provide a maximum range of 300 to 350 miles. Rack and pinion steering and high performance shocks on

front and rear will provide excellent handling.

The typical payload of the vehicle will consist of the required missile launcher, a land navigator, a forward looking infrared vision system, a laser rangefinder, a stereo vision camera, and the control link. These modular components can be mounted on the platform in the most advantageous position for that particular payload and mission.

The control link will consist of a fiber optic link backed up by a radio control link. The radio control backup will prevent the vehicle from getting stranded if the fiber optic cable is damaged.

VII. CONCLUSIONS/RECOMMENDATIONS

There are very few commercially available remotely controlled roving vehicles to be found. Of those located, the Emerson Electric Fast Attack Vehicle seems to be best suited to the task of the remotely controlled missile launcher vehicle. This decision is based on the assumption that the FAV will have comparable survivability to the AM General Hummer. Modifications are recommended for the FAV including the elimination of creature comforts, a fiber optic control link, and the addition of run-flat tires.

A conceptual design of a proposed special purpose vehicle is included in section IV.2. This design includes run flat tires, a flat platform on which to mount various payloads, a rear mounted 2-2.5 liter air-cooled gasoline engine, a 3 speed automatic transmission, and four wheel drive. The vehicle has a large ground clearance, while maintaining a relatively low profile. A fiber optic control link backed by radio control is recommended for redundancy.

Further research and field testing will be needed in order to determine the practical feasibility of various remote control schemes and candidate payloads. This can be done in several ways. The Grumman RCTV refurbished lunar rover is currently available to the Army to use as a breadboard type vehicle to field test candidate control systems and payloads. Testing should also be done on the

FAV and the Hummer since both are promising alternatives. An in depth study is needed concerning the trade-offs such as armor versus maneuverability, and cost versus survivability. This work is needed in order to definitively decide between a heavily armored vehicle, a light quick vehicle, or something in between.

Another thing to be considered is the possibility of using these vehicles in a dual mode: missile launching and reconnaissance. The control and guidance hardware needed for the vehicles to function as missile launchers is also sufficient for the vehicles to relay positions of vehicles back to the control center. The reconnaissance mode could still be valuable in the instance that a vehicle achieves a strategic position, but exhausts its missile payload.

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THE UNIVERSITY OF ALABAMA COLLEGE OF ENGINEERING

The College of Engineering at The University of Alabama has an undergraduate enrollment of more than 2,100 students and a graduate enrollment exceeding 125. There are approximately 100 faculty members, a significant number of whom conduct research in addition to teaching.

Research is an integral part of the educational program, and research interests of the faculty parallel academic specialties. A wide variety of projects are included in the overall research effort of the college, and these projects form a solid base for the graduate program which offers twelve different master's and five different doctor of philosophy degrees.

Other organizations on the University campus that contribute to particular research needs of the College of Engineering are the Charles L. Seebeck Computer Center, Geological Survey of Alabama, Marine Environmental Sciences Consortium, Mineral Resources Institute—State Mine Experiment Station, Mineral Resources Research Institute, Natural Resources Center, School of Mines and Energy Development, Tuscaloosa Metallurgy Research Center of the U.S. Bureau of Mines, and the Research Grants Committee.

This University community provides opportunities for interdisciplinary work in pursuit of the basic goals of teaching, research, and public service.

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